RESULTS ON THE CMB7 RECEPTOR MODELLING IN THE VAAL TRIANGLE

by

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INTRODUCTION

The deteriorating air quality and general degradation of the environment in industrialized and urban regions of South Africa have been of public concern for more than a decade. The detrimental health effects, obscured visibility and damage to property have prompted the public, authorities and industry alike to take the appropriate action.

Air pollution is a significant problem, not only in the Vaal Triangle and on the Eastern Transvaal Highveld, but also in the metropolitan areas of Cape Town, Durban and other urban regions. With the rapid urbanization taking place, more people are being exposed to air pollution, generated not only by industry, but also by the growing population itself.

A recent health study conducted by the Medical Research Council, on school children from the Vaal Triangle, clearly demonstrated the relationship between deficient air quality in that area and the resultant respiratory diseases.

In excess of 80 per cent of South Africa's primary energy comes from coal combustion, either in the form of electrical power generation, the manufacture of synthetic fuel, or domestic coal combustion. Emission from the combustion of coal are, directly or indirectly responsible for the major proportion of the man-made air pollution in our industrialized regions. Approximately 30 per cent of the South African population, more so in the rural areas of South Africa, are dependent on the combustion of wood as their primary source of energy. The National Air Pollution Advisory Committee (NAPAC) recently drafted a list of priorities, which elucidates issues such as smoke pollution from black residential areas, motor vehicle emissions, waste dump combustion, spontaneous coal dump combustion, and global air pollution.

Key question that were addressed are:

(i) How great is the air pollution problem, and how do the measured values in a specific region compare with internationally accepted standards?
(ii) What are the mean 24 hr and annual pollution levels, are well as the worst case scenarios?
(iii) Which polluting processes contribute to the ambient air in a specific region?
(iv) How much is contributed by each of the polluting source types at a specific site over a given sampling period?

Once these questions have been addressed in a scientific and quantitative manner, the authorities and industry alike will be in a favourable position to take the appropriate action towards resolving the problem.

An environmental impact study should form an integral part of any housing or industrial development plan. Data from studies such as the one presently being undertaken in the Vaal Triangle by Mintek are of great importance to urban planning. In the planning of residential areas, attention should be paid to aspects such as electrification and alternative sources of energy. Thought should also be given to having paved roads in such areas, since of the contribution to air pollution of the fugitive dust from dirt roads, already polluted with lead from petrol, could be significant.

It is necessary not only to conduct limited studies in areas such as the Vaal Triangle and the Eastern Transvaal Highveld, but also to extend these measurements to encompass an on-going National monitoring network, whereby samples can be taken on a continuous basis over 24 hr or 7 day sampling periods. To conduct such a study the collaboration of the government, the local health authorities, industry, and the public is essential.

All the source and ambient data is being compiled into a National data base, and in a format which can easily be retrieved by researchers, authorities and the public. As new data is being generated the data base will be updated.

All procedures applied by Minted comply with the USA EPA standards, and procedures prescribed by the Desert Research Institute (DRI) in Reno, Nevada, USA. The DRI has, furthermore, been acting as the external auditor of our procedures and reports.

MINTEK'S INVOLVEMENT

Mintek has over the past 5½ years been actively involved with the sampling and chemical analyses of aerosol samples from polluting sources as well as the ambient atmosphere in the Vaal Triangle and on the Eastern Transvaal Highveld. Three reports, (1) "Pilot Study in Source Apportionment of Atmospheric Particulates in the Vaal Triangle", (2) "The Establishment of Chemical Source Profiles, and their Application to the Apportionment of Aerosols in the Vaal Triangle", and (3) "The Establishment of Chemical Source Profiles from Industrial and other Emissions on the Eastern Transvaal Highveld" were published during the last three years. Mintek recently declassified the last two reports, and copies thereof are available to the public. The current project "Ambient Sampling and Source Apportionment in the Vaal Triangle" was recently completed. This involves the ambient sampling, chemical analyses of the filters, as well as the modelling of all the source and ambient chemical data at three sites in the Vaal Triangle for week long intervals over a period of one year. The receptor modelling involves apportioning of data in such a way that the contributions by the various source types to the ambient atmosphere are quantified.

USA COLLABORATION

The above mentioned projects were conducted in collaboration with Drs. John Watson and Judith Chow of the Desert Research Institute (DRI) in Reno, Nevada. Guidelines and standards set by the US EPA are being followed with all our studies on air pollution. The DRI has, furthermore, been doing the carbon analyses on all the samples collected during our campaigns. Dr. Chow and other prominent scientists from the DRI have visited South Africa twice, and Dr. Chow was responsible for auditing the Vaal Triangle, and the Eastern Transvaal Highveld source profile reports.

SAMPLING EQUIPMENT

Mintek has established its expertise in the field of earosol sampling and analysis. A universal sampling system, configured as a dilution stack sampler to collecting source samples from stacks and ducts (Fig. 1) as a re-suspension sampler (Fig. 2), or as an ambient sampler (Fig. 3, 4), was designed and built by Mintek in 1992, Depending on the configuration, the particulate bearing air from the suspension chamber or ambient atmosphere is drawn through either the coarse (PM_{10}) or fine ($PM_{2.5}$) size-selective inlets, and onto the filters (Fig. 5). The particulate matter is retained on the filters for chemical analyses. A controls enclosure containing the mass flow control system and vacuum pump is located below the suspension chamber enclosing the size selective inlets and four filters holders.

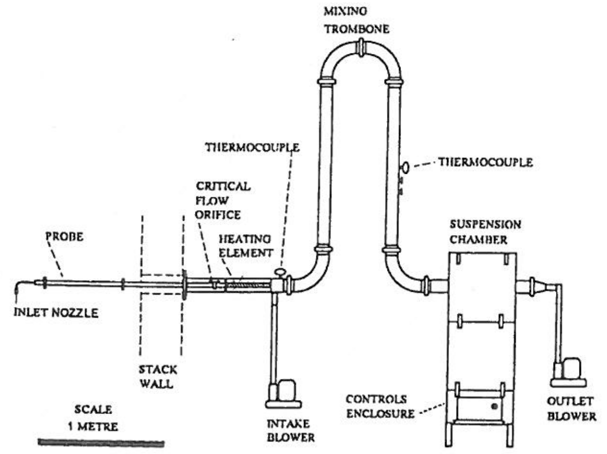

Figure 1. The complete dilution stack sampling unit. Either PM_{10} or $PM_{2.5}$ size-selective inlets are installed on the four filter holders enclosed in the suspension chamber.

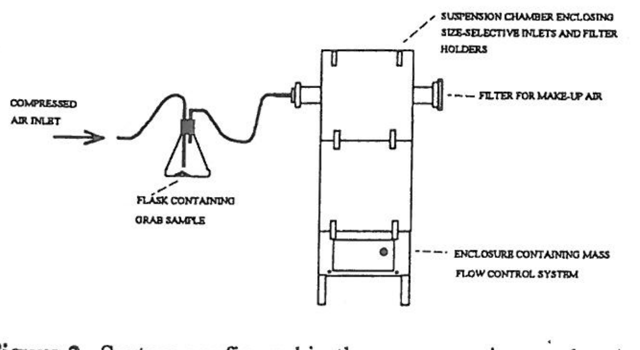

Figure 2. System configured in the re-suspension mode. A screened sample is puffed into the suspension chamber with compressed air. Either PM_{10} or $PM_{2.5}$ size-selective inlets are installed on the four filter holders enclosed in the suspension chamber.

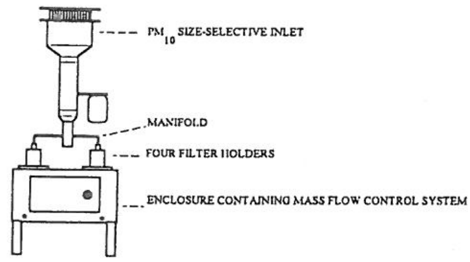

Figure 3. System configured in the ambient sampling mode with the PM_{10} (<10 micron) size-selective inlet mounted on the four filter holders.

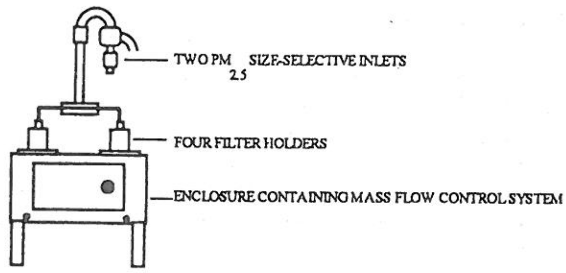

Figure 4. System configured in the ambient sampling mode with the two $PM_{2.5}$ (<2.5 micron) size-selective inlets mounted on the four filter holders.

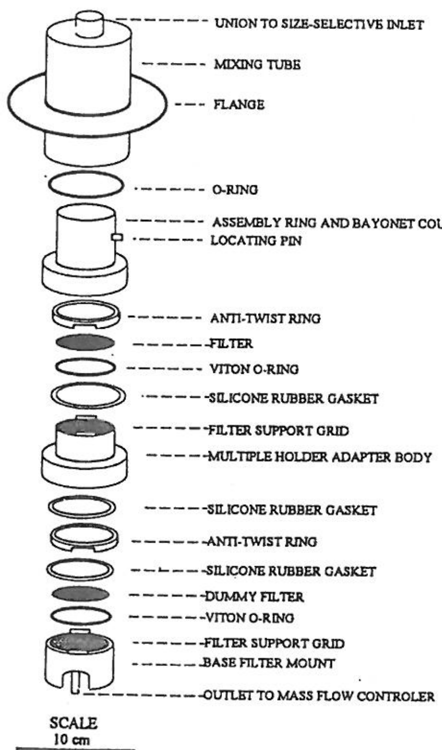

Figure 5. An exploded view of a filter holder.

SOURCE SAMPLING AND ANALYSIS

The filters are accurately weighed and thereafter submitted to the laboratories at Mintek and the DRI for chemical analyses. The 47 chemical species analysed for include the 36 elements: Na, Mg, Al, Si, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Sr, Y, Zr, Ag, Cd, Sn, Sb, Te, Cs, Ba, Ce, Hg, Tl, Pb, Bi, U, the 4 ions NH_4^+, NO_3^-, $SO_4^=$ and Cl^-, as well as the 7 organic (O) and elemental (E) carbon species O1TC, O2TC, O3TC, O4TC, E1TC, E2TC, and E3TC. For each process, the concentrations of these 47 species together comprise the chemical source profile or fingerprint. Analytical procedures include X-ray fluorescence spectrometry (XRF), inductively coupled plasma mass spectrometry (ICP-MS), atomic absorption (AA) spectroscopy, ion chromatography, inductively coupled plasma emission spectrometry (ICP-ES) and thermal/optical reflectance (TOR) carbon analyses. Mintek recently acquired a Spectro energy dispersive XRF system which has been set up to simultaneously analyse 26 chemical elements on the filters. Examples of chemical source profiles or fingerprints are given in Figures 6 to 9. There were 35 source profiles measured in total, 19 from the Vaal Triangle and 16 from the Eastern Transvaal Highveld. Measured sources include 4 coal fired power plants, 3 domestic coal fires, 3 biomass burning, coking furnace, smouldering coal discard dump, oil/gas boiler, 5 arc furnaces, rotary kiln, basic oxygen furnace, sinter plant, shaking ladle, direct reduction furnace, AOD converter, ferro-silicon-manganese plant, ferro-silicon plant, motor vehicle emissions, recovery furnace, lime kiln, fugitive coal dump dust and 2 fugitive soil dust samples.

AMBIENT SAMPLING AND MODELLING

The ambient air sampling campaign in the Vaal Triangle spanned a period of one year, during which samples of the respirable (PM_{10}) airborne particulates were collected for week long periods at three sampling stations in the commercial centres of Vereeniging, Vanderbijlpark and Sasolburg. These filters were handled and analysed in a similar fashion as the source samples. The gravimetric data from each of the three sampling stations are represented graphically in Figure 10. This clearly illustrates the increased pollution levels during the late Autumn and Winter periods, with peaks approaching, and exceeding the 24 hr National Ambient Air Quality Standard (NAAQS) of 150 micrograms per cubic meter during four individual weeks in Vereeniging, and during one week in Vanderbijlpark. The mean annual NAAQS of 50 micrograms per cubic meter was exceeded most of the time except during the summer months. It can, furthermore, be seen that in general the Vereeniging (annual mean value 70.15 micrograms per cubic meter) and Vanderbijlpark (annual mean value 58.15 micrograms per cubic meter) pollution levels are greater than for Sasolburg (annual mean value 57.53 micrograms per cubic meter).

Some of the ambient chemical data from the first six months of the study, together with the source profile chemical data were modelled using the Chemical Mass Balance version 7 (CMB 7) receptor model of the US EPA. The goal with this campaign is to apportion *i.e.* quantify the contributions of each polluting source-type. The mean seasonal source apportionment results are presented in Figures 11.1 to 11.4 for all three sites used in the Vaal Triangle study. In general the modelling shows that major contributions originated from soil dust, domestic coal combustion, secondary ammonium sulphate, iron arc furnaces and power station flyash with smaller contributions coming from sinter plant emissions, secondary ammonium nitrate, coking furnace, petrol vehicle and ferro-manganese arc furnace emissions. CMB7 modelling for week long sampling intervals over a period of a year,

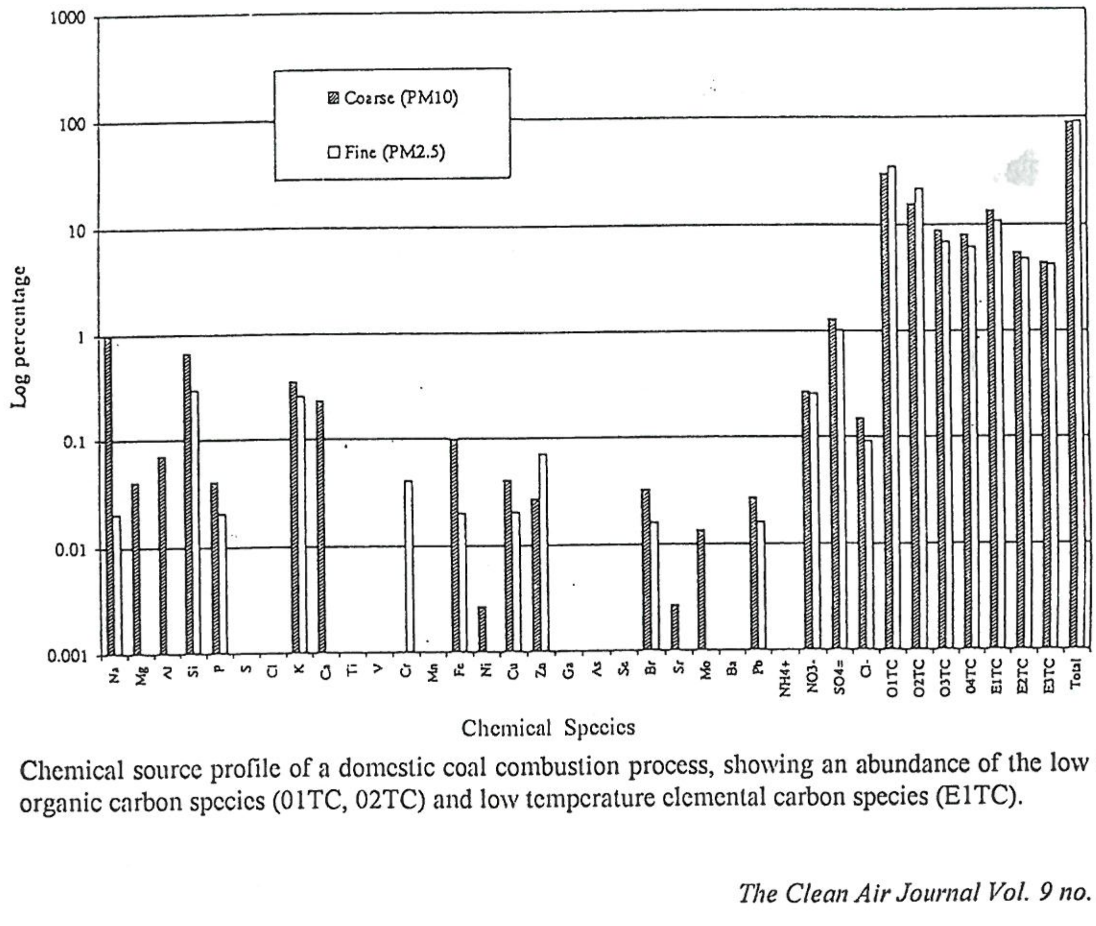

Figure 6. Chemical source profile of a domestic coal combustion process, showing an abundance of the low temperature organic carbon species (01TC, 02TC) and low temperature elemental carbon species (E1TC).

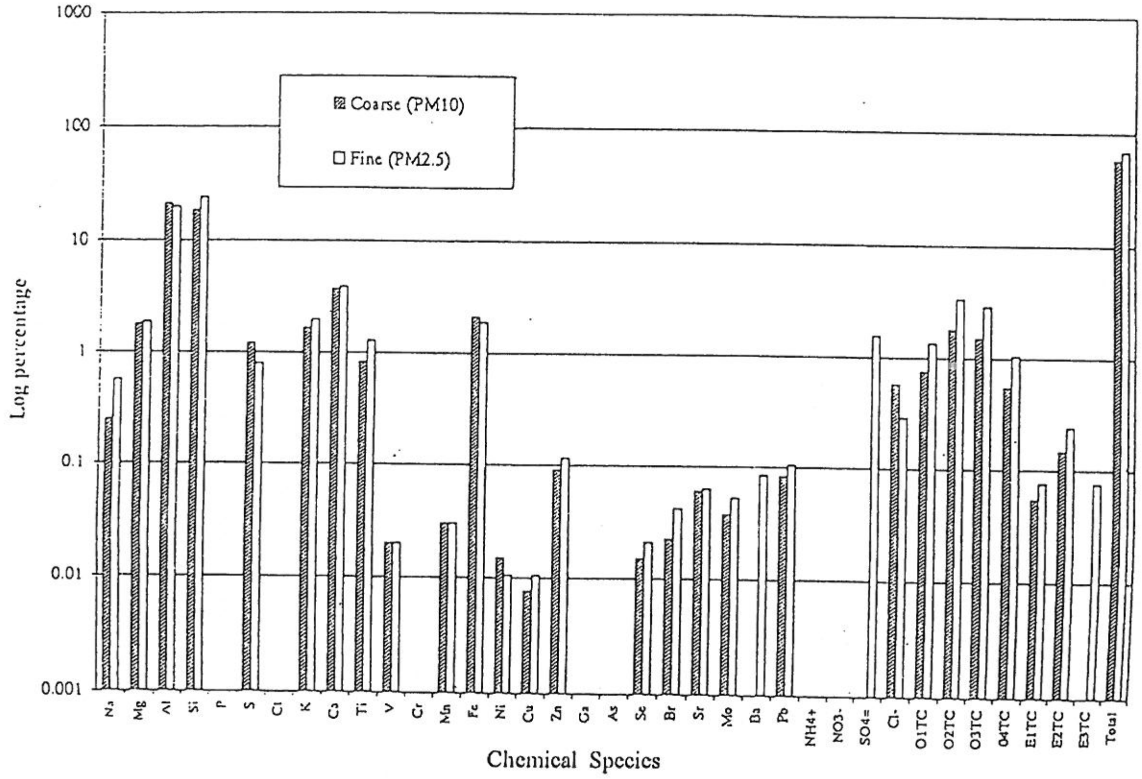

Figure 7. Chemical source profile of the Lethabo coal fired power plant fly ash. The chemical species of significance include Mg, Al, Si, K, Ca, Fe and Se.

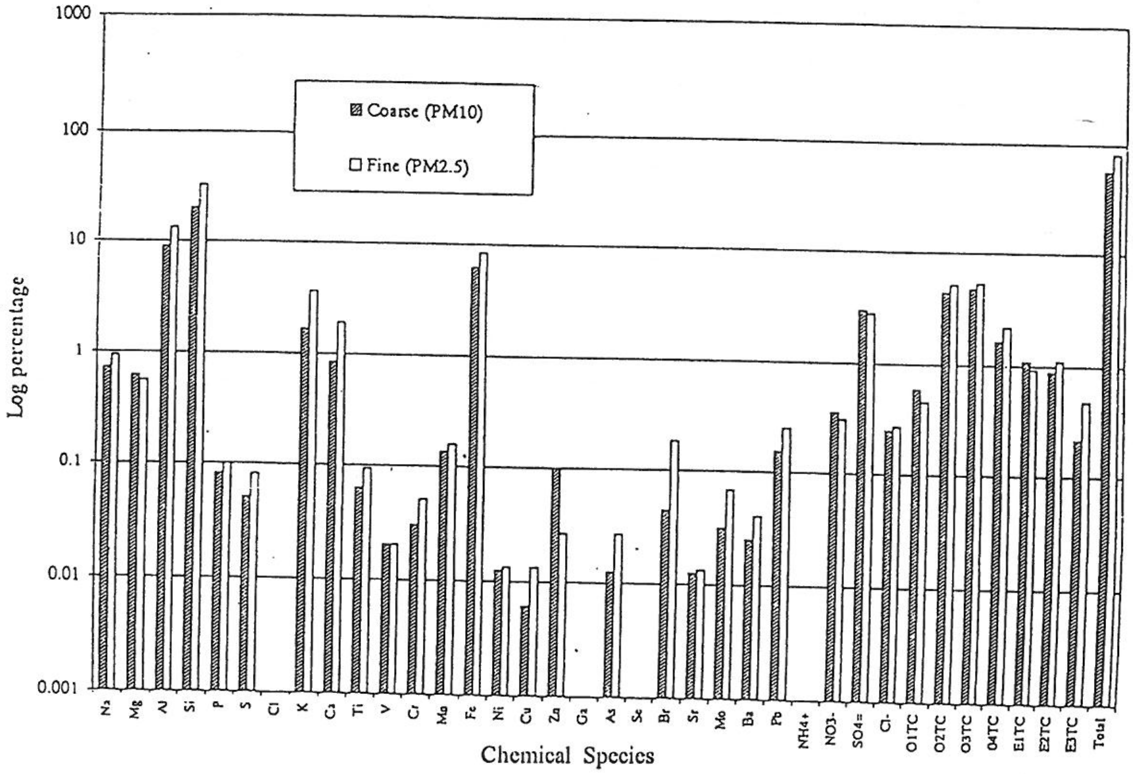

Figure 8. Chemical source profile of soil collected in the Sasolburg area. The chemical species of significance include Al, Si, K, Ca, Fe as well as $So_4^{=}$ and some of the organic carbon species.

at each of the three sampling stations in Vereeniging, Vanderbijlpark and Sasolburg has been completed.

CONCLUSIONS

The annual air quality standard of 50 micrograms per cubic meter was exceeded at all three monitoring stations from April 1994 to March 1994. Weekly gravimetric concentrations exceeded 150 micrograms per cubic meter on four occasions at Vereeniging and once at Vanderbijlpark implying that the 24-hour standard may have bee exceeded at some time during those sampling weeks.

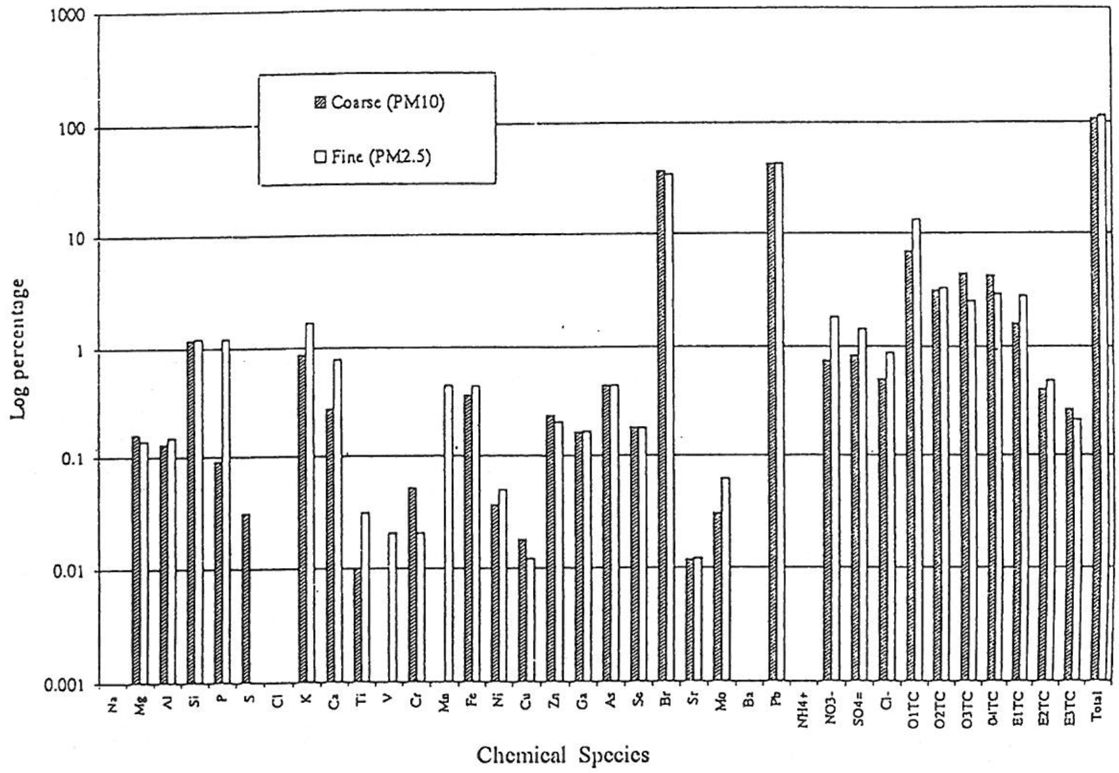

Figure 9. Chemical source profile of petrol vehicle exhaust emissions typically with high concentrations of Br and Pb.

Weekly gravimetric particulate loadings from april 1994 to April 1995

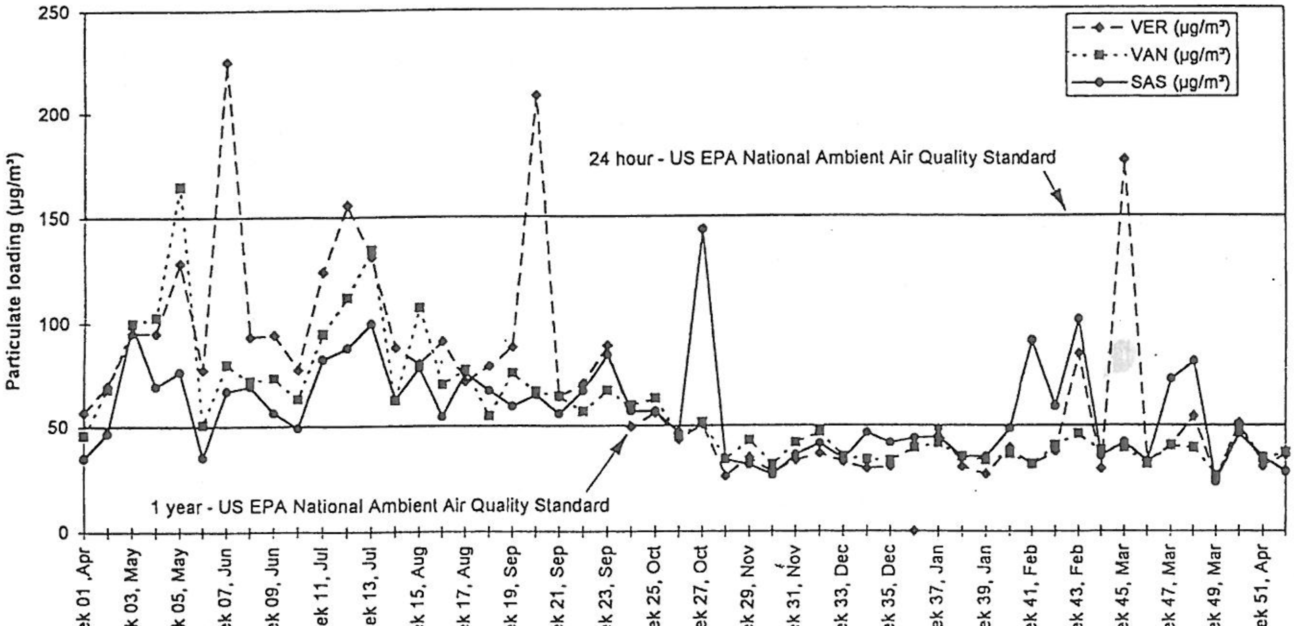

Figure 10. Plot weekly gravimetric data from Vereeniging, Vanderbijlpark and Sasolburg, for the period 22 April, 1994 to 21 April, 1995. The 24 hr (150mg/m³) and 1 yr. (50mg/m³) US-EPA National Ambient Air Quality Standards (NAAQS) are shown.

Soil dust, coal combustion and secondary ammonium sulphate are the largest contributors to the poor air quality in the Vaal Triangle.

This paper is directed at the authorities and the private sector and calls for support of continuous air monitoring in the areas where pollution is of concern. Closer collaboration with such organizations such as the US EPA and the DRI should be sought so as to ensure the highest quality of research and credibility of the results. Once these questions have been addressed in a scientific and quantitative manner, the authorities and industry alike will be in a favourable position to take the appropriate action towards resolving the problem.

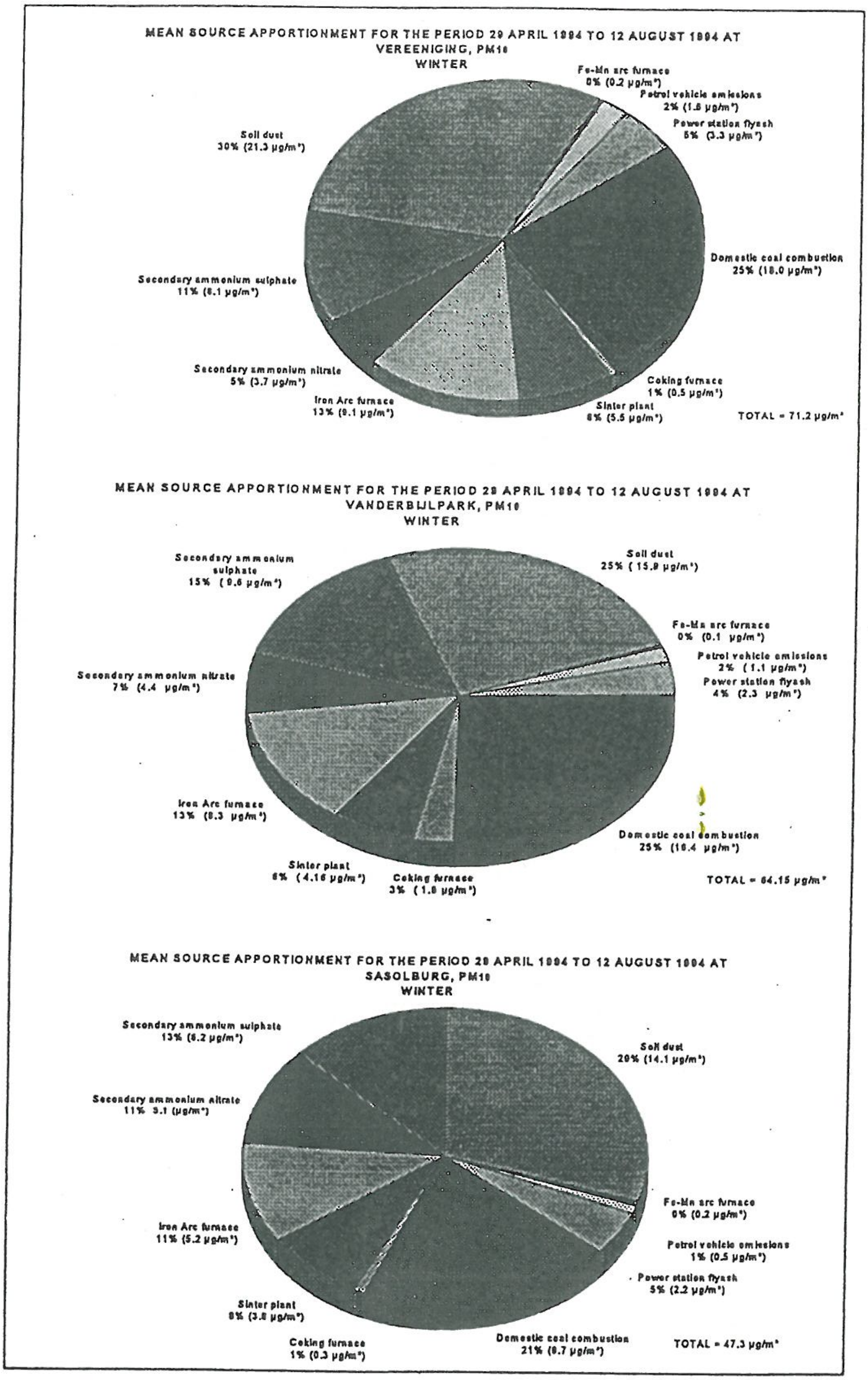

Figure 11.1 Mean source apportionment for the period 29 April 1994 to 12 August 1994 at all three sites.

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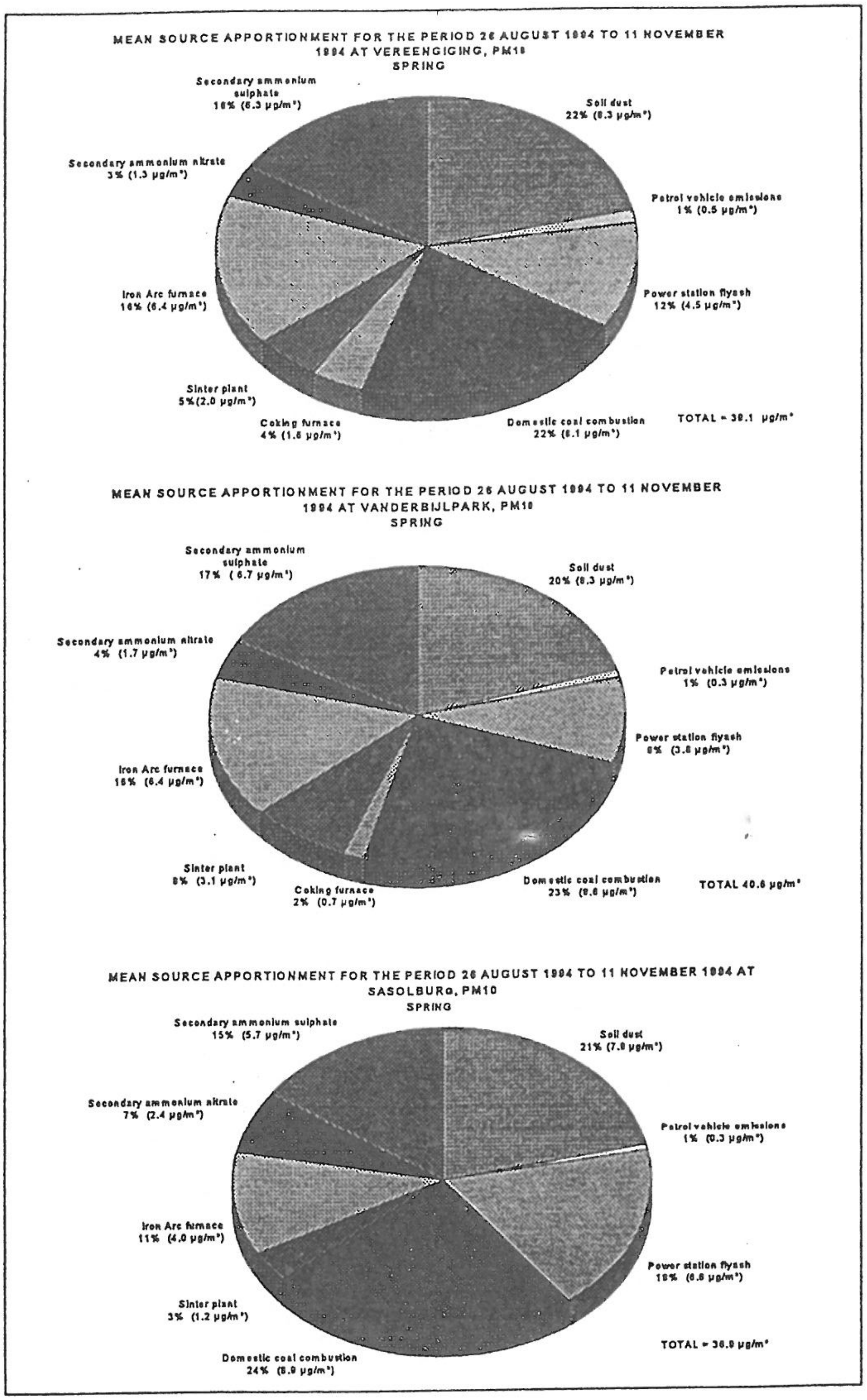

Figure 11.2. Mean source apportionment for the period 26 August 1994 to 11 November 1994 at all three sites.

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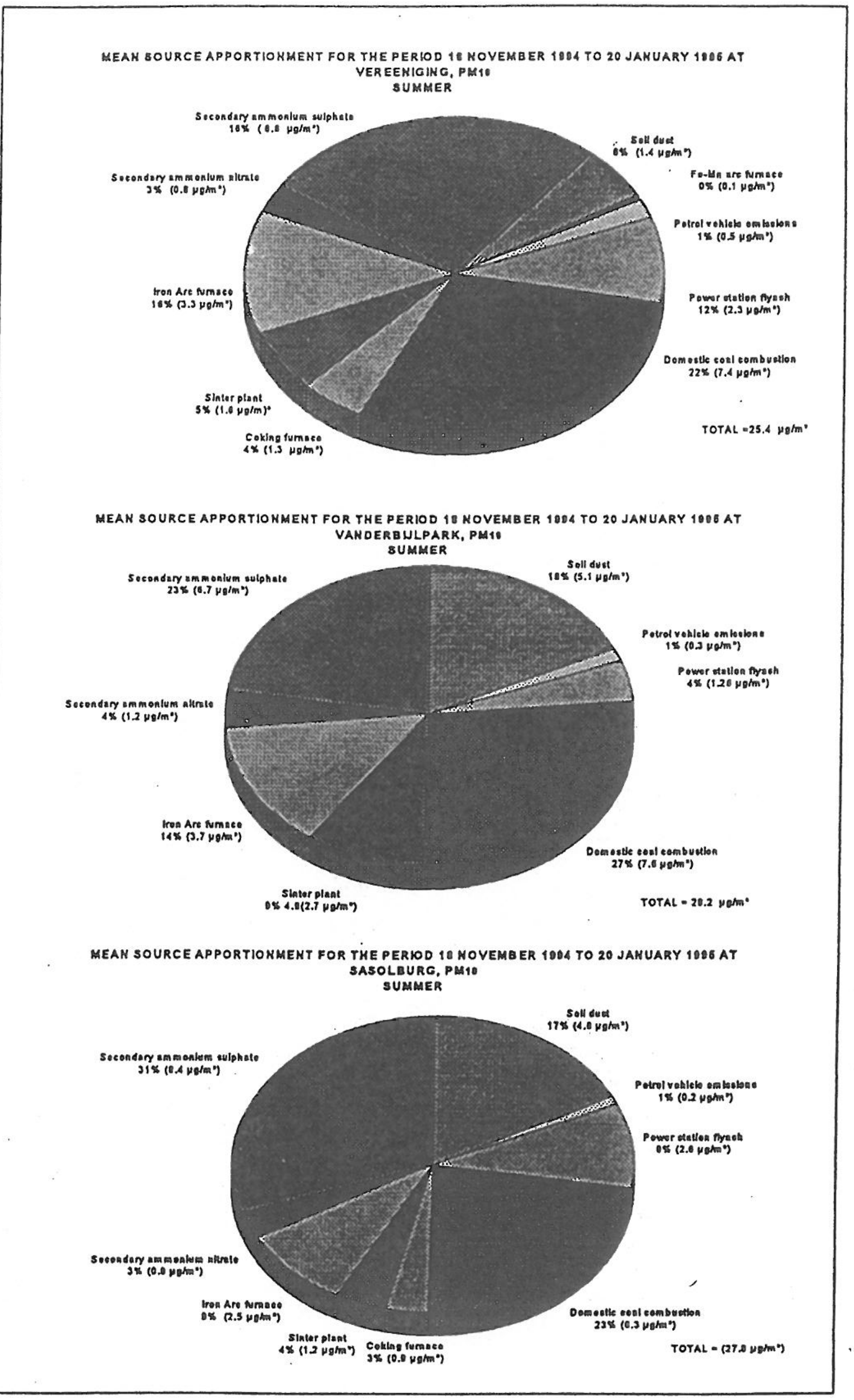

Figure 11.3. Mean source apportionment for the period 18 November 1994 to 20 January 1995 at all three sites.

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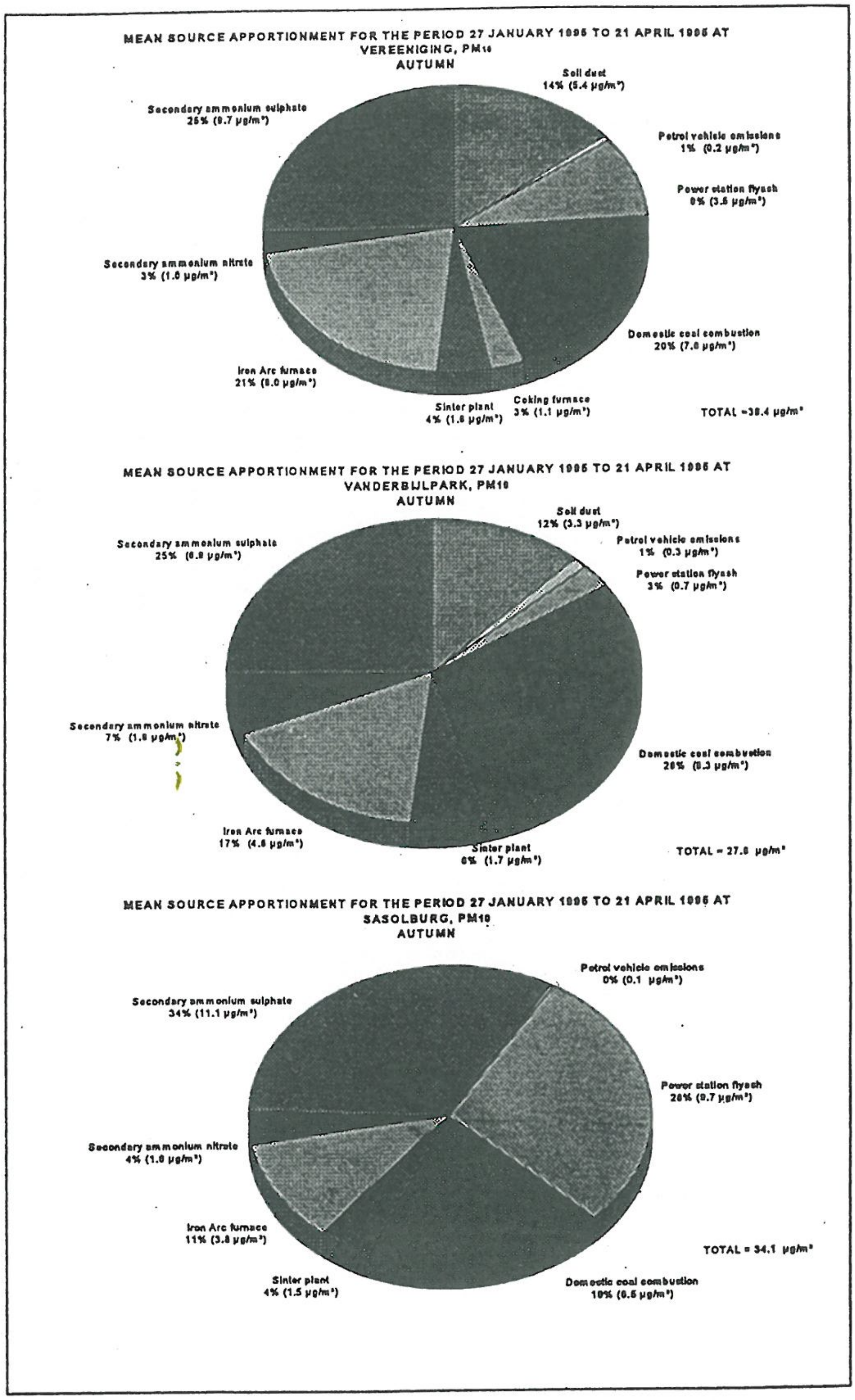

Figure 11.4. Mean source apportionment for the period 27 January 1995 to 21 April 1995 at all three sites.